

**Preliminary  
Project Execution Plan  
for the  
Electron Beam Ion Source Project  
(EBIS)**

**Project # 06-SC-002**

**at  
Brookhaven National Laboratory  
Upton, NY**

**For the U.S. Department of Energy  
Office of Science  
Office of Nuclear Physics (SC – 26)**

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**Preliminary Project Execution Plan  
for the  
Electron Beam Ion Source Pre-Injector  
(EBIS)  
at Brookhaven National Laboratory**

**CONCURRENCES:**

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James G. Alessi  
EBIS Contractor Project Manager

---

Date

---

Derek I. Lowenstein  
Chairman, Collider-Accelerator Department  
Brookhaven National Laboratory

---

Date

---

Samuel Aronson  
Associate Laboratory Director for High  
Energy and Nuclear Physics  
Brookhaven National Laboratory

---

Date

---

Michael A. Butler  
EBIS Federal Project Director  
DOE Brookhaven Site Office

---

Date

---

Michael D. Holland  
Manager  
DOE Brookhaven Site Office

---

Date

---

Frank M. Sulzman  
Space Radiation Program Manager  
NASA Headquarters

---

Date

---

Jehanne Simon-Gillo  
Director for Facilities and  
Project Management Division, Acting  
Office of Nuclear Physics,  
Office of Science

---

Date

---

Daniel R. Lehman  
Director  
Office of Project Assessment  
Office of Science

Date: \_\_\_\_\_

**APPROVED:**

---

Dennis G. Kovar  
Associate Director  
Office of Nuclear Physics,  
Office of Science

---

Date

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## **1 INTRODUCTION**

Brookhaven National Laboratory (BNL), located in Upton, NY, is owned by the U.S. Department of Energy (DOE) and operated by Brookhaven Science Associates (BSA) under the U.S. Department of Energy Contract No. DE-AC02-98CH10886. The flagship Nuclear Physics facility at BNL is the Relativistic Heavy Ion Collider (RHIC).

Successful RHIC operations depend on an accelerator complex that accelerates ions to intermediate energies leading up to RHIC injection. This process starts in the Tandem Van de Graaff heavy ion pre-injector. BNL is proposing to construct a new heavy ion pre-injector for RHIC, the Electron Beam Ion Source (EBIS), which will lead to more reliable, cost-effective operations and new capabilities. This project will provide a new heavy ion pre-injector for RHIC, based on a high charge state heavy ion source, a Radio Frequency Quadrupole (RFQ) accelerator and a short Linear accelerator (Linac).

Critical Decision Zero (CD-0) was approved in August 2004. The total estimated cost (TEC) approved at CD-0 is approximately \$12 million to \$17.5 million dollars for the full proposed technical scope and the preliminary Total Project Cost (TPC) is approximately \$16 million to \$19.5 million, if funded only by the DOE Nuclear Physics Program. Since CD-0 approval, a Statement of Work between BNL and the National Aeronautics and Space Administration (NASA) has been signed, in which NASA will contribute \$4.5 million to the project costs. Based on NASA's contribution and detailed bottoms-up estimate, the current preliminary estimate of the DOE TPC range is \$12.1 million - \$14.8 million. R&D and conceptual design was supported in FY 2005. project design and construction starts in Fiscal Year (FY) 2006 and the project is complete in early FY 2010.

This preliminary Project Execution Plan (PEP) describes the coordination of efforts of the project team, including the processes and procedures used by the EBIS contractor project manager (CPM) and Federal Project Director (FPD) to ensure that the project is completed on time and within budget. The PEP defines the preliminary project scope and the organizational framework, identifies roles and responsibilities of contributors, and presents the work breakdown structure (WBS) and schedule. The PEP also describes the formal change control process by which project cost, schedule, or scope may be revised in consultation with the FPD and the DOE Office of Science, Office of Nuclear Physics.

## **2 MISSION NEED**

The mission of the Nuclear Physics (NP) program is to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy and develop the scientific knowledge, technologies and trained manpower that are needed to underpin the DOE missions for nuclear related national security, energy and environmental quality. As part of its strategic mission, the NP program plans, constructs and operates major scientific user facilities and fabricates experimental equipment to serve researchers at universities, national laboratories and industrial laboratories. The program provides world-class, peer-reviewed research results in the scientific disciplines encompassed by the NP mission areas under the mandate provided in Public Law 95-91 that established the department.

EBIS provides research capabilities that directly support the NP mission and address the NP Program Goal 05.20.00.00 to understand the evolution and structure of nuclear matter from the smallest building blocks, quarks and gluons, to the elements in the universe created by stars. A main objective of this nuclear science field is searching for the quark-gluon plasma and other new phenomena that might occur in extremely hot, dense plasma of quarks and gluons believed to have filled the universe about a millionth of a second after the “Big Bang.” Most of the world’s current experimental effort on this question is carried out using relativistic heavy-ion collisions at RHIC, which is supported by the DOE NP program.

The present pre-injector of heavy-ions for RHIC uses Tandem Van de Graaff accelerators built around 1970. The beam is transported to the Booster accelerator via an 860-meter long line. The successful development of an EBIS prototype at BNL makes it possible to replace the present pre-injector with a reliable, low maintenance and cost effective Linac-based pre-injector. This new pre-injector would consist of an EBIS high charge state ion source, an RFQ accelerator and a short Linac. EBIS would increase the reliability and efficiency of RHIC operations, reduce the costs of RHIC operations and provide new experimental capabilities.

EBIS supports the Science Strategic Goal within the DOE’s Strategic Plan to protect national and economic security by providing world-class scientific research capacity and advancing scientific knowledge. More specifically, this effort supports the General Goal within the DOE Strategic Plan:

“General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to ensure the success of Department missions in national and energy security, to advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental and computational sciences and to provide world-class facilities for the Nation’s science enterprise.”

The proposed pre-injector system would also provide for a major enhancement in capability for the NASA Space Radiation Laboratory (NSRL), which utilizes heavy-ion beams from the RHIC complex. EBIS would allow for the acceleration of all important ion species for the NASA radiobiology program, such as, helium, argon, and neon which are unavailable with the present Tandem injector. In addition, the new system would allow for very rapid switching of ion species for NSRL experiments, reducing delays due to the interference with RHIC injection operations, and allowing enhanced mixed radiation-field studies.

The EBIS pre-injector project (EBIS source, Linac and RFQ) has been endorsed several times by a variety of panels. Most recently, the 2004 Machine Advisory Committee, organized by BNL, stated: “The committee strongly recommends launching a project as soon as possible to replace the present Tandem facility by an EBIS source followed by the RFQ and 2 MeV/u Linac.” And at the DOE 2003 RHIC Facility Review, the

committee stated: “The replacement of the Tandems by an EBIS source has merit and the DOE and BNL are encouraged to implement this.”

The new pre-injector offers the following advantages:

- Replacement of the two Tandems as the Booster preinjector, resulting in more stable beam intensities.
- Elimination of the need to use the 860-meter long transport line from Tandem to Booster; using instead a much simpler and economic 30-meter long line from EBIS to reduce setup time and allow fast switching between beams of different rigidities.
- Simplification of Booster injection scheme.
- Capability to provide ions not presently available for the NASA program, such as noble gas ions (major components of galactic cosmic rays), as well as more massive ions such as uranium and, with additional enhancements, polarized  $^3\text{He}$ , for the RHIC program.
- Increased flexibility to handle the multiple needs of RHIC, NSRL and Alternate Gradient Synchrotron (AGS). Two Tandems are needed for fast beam switching, while the EBIS preinjector will be able to switch species on a pulse-to-pulse basis.
- Improvements in reliability, setup time and stability should lead to increased integrated luminosity in RHIC and increased productivity for NSRL.
- Reduced operating costs. The Tandem facility requires a staff of approximately 12 Full Time Equivalents (FTEs) to support maintenance and a 24-hour shift rotation during operations. The Linac-based pre-injector should be able to run unattended at most times, as with the present proton Linac, and will require only a staff of approximately 3 FTEs.

If the new EBIS pre-injector is not built, significant upgrades to the Tandems will be required in order to ensure reliable long-term operation for RHIC and NSRL. This is discussed in more detail in Section 4.6.

### 3 FUNCTIONAL REQUIREMENTS

The technical objectives of the new pre-injector need to meet requirements of both the RHIC and NASA NSRL experimental programs. The corresponding technical scope and performance specifications required at Critical Decision-4 (CD-4) are described in Table 4.1. The system parameters desired from a new pre-injector are as follows:

- **Species: d to U.** The EBIS will produce helium to U beams. A deuterium beam may be produced in a simple plasma source injecting directly into the RFQ. The RFQ, Linac, and transport lines must be designed to handle all species in this range. The species extracted from EBIS depend on the injected singly charged ions. With the external ion sources included in the present design, beams from typical gases and solids as required by RHIC and NSRL will be available. Production of some more exotic beams may require additional development or resources devoted to the external source of such ions for injection.

- **Intensity at injection into the Booster: up to  $1.1 \times 10^{11}$  charges/pulse with EBIS.** Species which have been run for RHIC and NSRL are shown in Table 3-1, along with intensities at Booster injection which are required in order to reproduce previously observed intensities. The EBIS pre-injector should at least match this performance in all cases.

Table 3-1 Beams and intensities at Booster input required to match past performance

Species	User	Q	Ions/pulse	Charges/pulse
Au	RHIC	32+	$2.7 \times 10^9$	$8.6 \times 10^{10}$
D	RHIC	1+	$2.5 \times 10^{11}$	$2.5 \times 10^{11}$
Cu	RHIC	11+	$1.0 \times 10^{10}$	$1.1 \times 10^{11}$
C	NSRL	5+	$2 \times 10^{10}$	$1 \times 10^{11}$
O	NSRL	8+	$6.7 \times 10^9$	$5.3 \times 10^{10}$
Si	NSRL	13+	$5 \times 10^9$	$6.5 \times 10^{10}$
Ti	NSRL	18+	$1.3 \times 10^9$	$2.4 \times 10^{10}$
Fe	NSRL	20+	$1.7 \times 10^9$	$3.4 \times 10^{10}$

- **Injected pulse width: variable, 10 – 40  $\mu$ s.** This allows 1-4 turn injection into the Booster. This simplifies the injection, and should greatly reduce the sensitivity to small beam losses at injection, which could otherwise lead to a pressure bump resulting in further beam loss.
- **Repetition rate: 5 Hz.** This keeps overall RHIC fill times to only a few minutes.
- **Switching time between two species: 1 second.** There are presently several operating scenarios for RHIC and NSRL, depending on, among other things, whether either is running alone, or the two are running concurrently. To allow operation with the desired flexibility, the new pre-injector must be able to switch beam species and transport line rigidity in 1 second.
- **Injection energy: 2 MeV/amu.** At present, injection from the Tandems is at 0.92 MeV/amu for Au. At this energy, there is a significant beam loss due to electron capture during Booster injection. By raising the injection energy to 2 MeV/amu, the capture cross section is reduced by a factor of 20-40.
- **Q/m: 0.16 or greater.** This ratio equals that presently delivered for Au from the Tandem. For lighter ions a higher q/m is required ( $\text{Si}^{13+}$ ,  $\text{Fe}^{20+}$ ) in order to achieve the desired Booster output energy for NSRL, within the rigidity constraints of the Booster and extraction transport lines.

## 4 PROJECT OVERVIEW

The project, including DOE and NASA contributions, includes the fabrication of an Electron Beam Ion Source for the production of high charge state heavy ions, plus the procurement of an RFQ and heavy ion Linac to accelerate ions from EBIS to a final energy of at least 2 MeV/amu. A transport line is to be fabricated to transport the beam from the output of the Linac to the existing Booster heavy ion injection point, as shown below in Figure 4.2. The project includes the fabrication or procurement of the dipole and quadrupole magnets, power supplies, diagnostics, vacuum components, and controls to properly operate the EBIS source, accelerators, and beam lines. The project also includes the assembly of subsystems, and the installation and testing of these subsystems in their final location in the equipment bay at the high energy end of the  $H^-$  Linac building.

The EBIS project is divided in four major systems, including (a) Source & Accelerator Structures; (b) Electrical Systems; (c) Mechanical Systems; (d) Facilities & Installation Support. The sections below describe the present conceptual design for the EBIS pre-injector for both the DOE and NASA efforts.

### 4.1 SOURCE & ACCELERATOR STRUCTURES

The Source & Accelerator Structures form the framework of the EBIS Pre-Injector. The superconducting solenoid, trap region electrodes, electron gun and electron collector are the major hardware items for the EBIS. External ion injection sources feed singly charged ions into the EBIS trap for further ionization to the desired final charge state. The Low Energy Beam Transport (LEBT) provides matching of the beam extracted from the EBIS into the RFQ. This line includes magnetic and electrostatic focusing and steering, and appropriate diagnostics. The RFQ provides initial acceleration of the beam to an energy sufficient for injection into a single Linac cavity. The Linac, an Interdigital-H (IH) structure in the present conceptual design, then accelerates the beam to the final required energy of 2 MeV/amu. The frequency presently chosen for both the RFQ and Linac is 101.28 MHz, which matches many existing Linacs and RFQs.

A layout of the pre-injector, as presently envisaged, is shown in Figure 4.1.

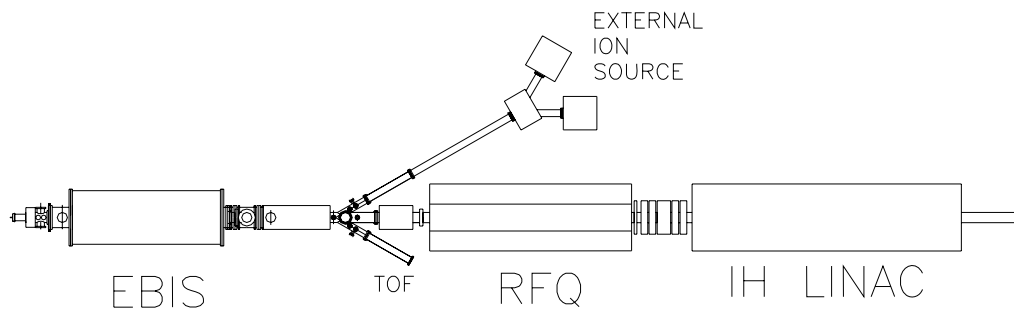


Figure 4.1 Conceptual layout of the pre-injector

## 4.2 ELECTRICAL SYSTEMS

The Electrical systems include all power supplies, diagnostic instrumentation, Radio Frequency (RF) systems and controls systems required for the operation of the EBIS, RFQ, Linac, and associated beam transport lines. There are five 101.28 MHz RF amplifier systems required, feeding the RFQ, IH Linac, and three buncher cavities. These systems will include amplitude and phase regulation, and cavity frequency tuning. Diagnostics include Faraday cups, current transformers, profile monitors, and time of flight spectrometers. Controls will be implemented in the same way as other recent installations such as the new polarized ion source and NSRL. All transport line diagnostics are similar to existing equipment, and applications software already exists. Vacuum equipment will be controlled via Programmable Logic Controllers (PLC's), with a PLC interface module to tie into the control system.

## 4.3 MECHANICAL SYSTEMS

The Mechanical Systems include both Magnet and Vacuum systems. Two 73-degree dipoles in the high energy beam transport line will bend beam into Booster. These dipoles will be able to switch field in 1 second, for fast changes in beam species. The High Energy Beam Transport (HEBT) line will use existing quadrupole and steering magnets. The vacuum systems will be sufficient to provide the required vacuum of  $10^{-9}$  to  $10^{-10}$  Torr in the EBIS trap region. Cryo pumping will be used on the RFQ and Linac.

## 4.4 FACILITIES & INSTALLATION SUPPORT

This includes facility modification, cooling systems and installation of the EBIS components. The new pre-injector will be housed in the lower equipment bay of Building 930 as shown in Figure 4.2. It will connect to the existing Tandem-to-Booster transfer line just before it enters the Booster electrostatic inflector. Cooling systems are required for the EBIS electron collector, EBIS magnets, RFQ and Linac cavities, and several power supplies.

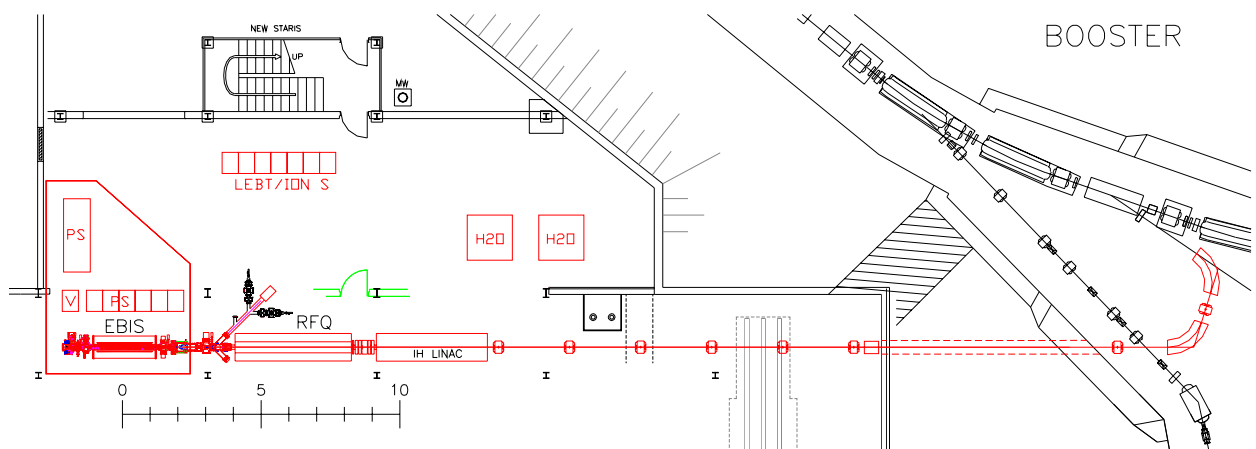


Figure 4.2 Placement of EBIS Pre-Injector in lower equipment bay of 200 MeV Linac.

#### **4.5 TECHNICAL SCOPE AND DELIVERABLES**

The DOE scope is the following activities or procurements:

- All Project Engineering and Design (PED), installation, and commissioning for the entire project
- All EBIS chambers, internal structures, and warm magnets
- The LEBT and external ion injection lines
- All vacuum components, controls, diagnostics, and cooling water systems
- All Medium Energy Beam Transport (MEBT) and HEBT beamline components, except for two HEBT dipoles
- All RF systems for operation of the RFQ, Linac, and bunchers
- All power supplies for EBIS, LEBT, and external ion sources, except for the electron collector and fast pulsing EBIS platform supplies.
- Electrical services required for the operation of the pre-injector

The NASA scope is the procurement of the following items:

- The EBIS superconducting solenoid
- The RF Quadrupole accelerator
- The Linac structure
- The buncher cavities
- The two HEBT dipole magnets and their power supplies
- The electron collector power supply
- All quadrupole magnet and steering magnet power supplies for the Linac, MEBT, and HEBT
- The fast pulsing power supplies for the EBIS drift tubes and platform bias.

Also included in the NASA scope is the installation of the beam port through the earth shielding between Linac and Booster.

The DOE deliverables are complete when all the items listed as DOE scope, above, have been procured or fabricated; the EBIS, RFQ, Linac, and beam transport lines have been installed; and the CD-4 requirements from the Table 4-1 below have been verified.

The NASA deliverables are complete when all the items listed as NASA scope, above, have been delivered to BNL, and the beam port is installed.

Table 4-1 CD-4 performance to be demonstrated at Booster input (measured on the current transformer located between the two HEBT 73 degree dipoles).

	<b>CD-4 Performance</b>	<b>Optimum Performance</b>
Species	Fe, Au	He to U (assuming appropriate external ion injection)
Intensity	$3 \times 10^8 \text{ Au}^{32+} / \text{pulse}$ $4 \times 10^8 \text{ Fe}^{20+} / \text{pulse}$	$2.7 \times 10^9 \text{ Au}^{32+} / \text{pulse}$ $4 \times 10^9 \text{ Fe}^{20+} / \text{pulse}$ $5 \times 10^{10} \text{ He}^{2+} / \text{pulse}$
Charge-to-mass ratio, Q/m	0.162 (Au) 0.357 (Fe)	$\geq 0.16$ , depending on ion species
Repetition rate	Demonstration of pulsing	5 Hz
Pulse width	10-40 $\mu\text{s}$	10-40 $\mu\text{s}$
Switching time between species	Demonstration of switching	1 second
Output energy	2 MeV/amu	2 MeV/amu

#### 4.6 ALTERNATIVE ANALYSIS

Substantial pre-conceptual Research & Development (R&D) has been carried out and the technology needed to realize an Electron Beam Ion Source meeting RHIC requirements has been developed, leading to a successful demonstration of the "proof of principle". Before selecting the EBIS, alternative high charge state heavy ion sources were considered; in particular the Electron Cyclotron Resonance (ECR) source, and the Laser Ion Source (LIS). The EBIS was chosen as best meeting the requirements for a new RHIC pre-injector, based on considerations such as intensity, reliability, flexibility in the choice of species, fast switching between species, etc.

The LIS has serious reliability problems, and the species it can produce are limited to those coming from solid targets, preferably with high melting points. Pulse-to-pulse switching of species is probably not possible.

The ECR source cannot produce a sufficient intensity of high charge state heavy ions to meet the RHIC requirements. In addition, it has less flexibility than an EBIS in the choice of ion species. Maximum ECR outputs vary considerably with species (it favors gases and low melting point metals). Pulse-to-pulse switching of species would be difficult to do with maximum intensity, since there is often a "memory" effect when changing species, meaning the source has to clean up over time after a change in species to reach optimum performance. A final concern with the ECR source is the increased difficulty of transporting and matching of these high current beams into an RFQ. The required charge states tend to be in the tail of the ECR charge state distribution for heavy beams, so only a few percent of the total current would be in the desired charge state, meaning that the total extracted current is very high, leading to space-charge problems in transport.

In contrast to the alternatives, the EBIS can meet the intensity goals. With the pre-conceptual R&D prototype, a factor of 20 increase in EBIS performance compared to previous EBIS's was achieved. To meet RHIC requirements, the EBIS must be scaled in the same manner by only another factor of 2. With the EBIS the required charge states can be easily produced, and the EBIS can produce ions of any species; and with external ion injection species can be changed on a pulse-to-pulse basis. The current produced is independent of species. At least 20% of the total current out of EBIS is contained in the charge state of interest for any EBIS beam, so the total current extracted remains at a reasonable level. Finally, with an EBIS, a fixed amount of charge per pulse is extracted, and the beam pulse width can be controlled to match optimally the Booster injection requirements.

The RFQ is the only technology choice for the first acceleration stage of the EBIS beam. The Interdigital-H (IH) Linac structure was chosen as the next acceleration stage in the baseline design. This is a low-risk choice, since there are many Linacs of this type in operation. The IH Linac used at CERN for acceleration of Pb, in particular, almost exactly meets the EBIS requirements. A superconducting heavy ion Linac was considered, but suffers from higher cost and increased operational complexity. During the future detailed design phase, alternative room-temperature Linac structures will be reconsidered.

An internal technical review of the pre-conceptual design was held on January 27-28, 2005, and the external committee of source and accelerator experts endorsed the choices made for both ion source and accelerators.

If the new Linac-based pre-injector is not built, significant upgrades to the Tandems will be required in order to ensure reliable long-term operation for RHIC and NSRL. Construction began for the Tandem Van de Graaff facility in 1966, and it was commissioned in 1970. Many of the Tandem systems date back to 1960's technology and need modernization. Should EBIS not be approved, alternative high cost (approximately \$9 million) risk mitigation plans will have to be initiated in order to prevent unexpected failures of the Tandem from suspending RHIC operations for extended periods. Alternatively stated, the EBIS project would provide potential contingency in scheduling of the RHIC accelerator. Upgrading the Tandems will not lead to new performance capabilities that are needed for the long-term plans for the RHIC facility or NSRL.

The 2004 BNL Machine Advisory Committee stated: "...[T]he two tandems, which have successfully been used for 35 years to provide particles to the AGS complex, have suffered during the recent years from a large number of repetitive failures. They would need a large renovation program with near-term costs estimated at \$6 million (and another \$3million in the medium term), if planned to be used in the future. Moreover, the tandem facility requires intense maintenance, with a considerable effort of human resources...The committee does not recommend investing such a large amount of resources on an out-of-date technology and for which components are more and more difficult to find."

## 5 MANAGEMENT ORGANIZATION

### 5.1 GENERAL

This document provides the management organization for the EBIS as defined for the development, construction and final assembly. Figure 5-1 outlines the management structure proposed for EBIS.

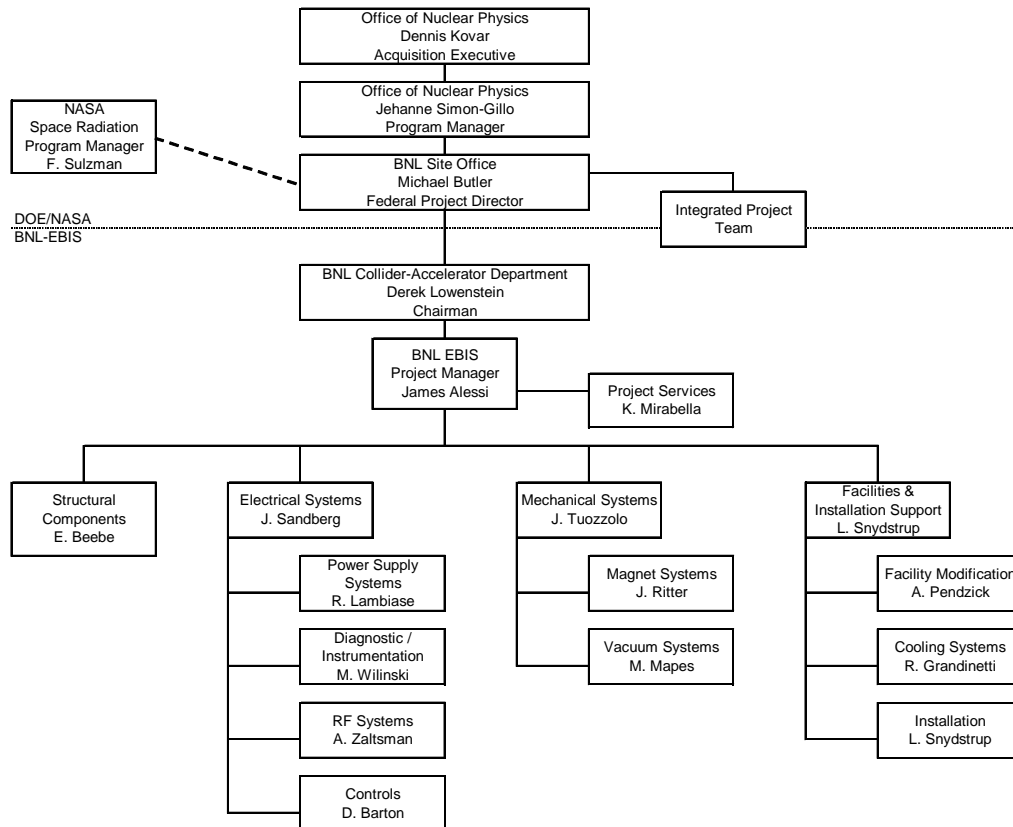


Figure 5.1 Management Organization Chart for EBIS

### 5.2 PROJECT MANAGEMENT RESPONSIBILITIES

#### 5.2.1 Department of Energy

Within the DOE Office of Science (SC), the Office of Nuclear Physics (NP) has overall DOE responsibility for the EBIS project.

#### Responsibilities

The Acquisition Executive is Dennis Kovar, Associate Director of the Office of Science for Nuclear Physics (SC-26).

- Approves approval of Level “0” baseline changes.

Jehanne Simon-Gillo is the Federal EBIS Program Manager. The EBIS Program Manager's responsibilities include:

- Provides programmatic direction.
- Functions as DOE headquarters point of contact for the project matters.
- Oversees project progress and organizes reviews as necessary.
- Budgets for funds to execute the project.
- Controls changes to project baselines in accordance with the PEP.
- Recommends approval of Level "0" baseline changes.

Michael A. Butler at the Brookhaven Site Office (BHSO) is assigned as the Federal Project Director. The Federal Project Director responsibilities include:

- Overall responsibility for planning, implementing, and completing EBIS.
- Provides overall project management oversight.
- Issues key work authorization.
- Provides necessary funds via approved financial plans.
- Manages and allocates the contingency funds according to the procedure defined in the Baseline Change Control (Section 7).
- Submits key project documents and critical decisions to DOE and report project progress.
- Ensures that the project complies with applicable ES&H requirements (e.g., National Environmental Policy Act [NEPA] requirements).
- Approves Level 1 Baseline changes.

### **5.2.2 NASA**

Frank M. Sulzman, Space Radiation Program Manager, NASA Headquarters is the NASA representative to the EBIS Project.

#### **Responsibilities**

- Functions as NASA point of contact for project matters.
- Reviews relevant project documentation
- Participates in monthly and quarterly Project teleconferences, as well as key Project reviews (Preliminary Design Review, Critical Design Review, Operational Readiness Review, etc.)

### **5.2.3 Brookhaven National Laboratory**

#### **Chairman for the Collider-Accelerator Department at BNL**

Funding for this project will be directed through BNL's Collider-Accelerator Department (C-AD). Fiscal and management responsibility for the fabrication of EBIS will reside with the Chairman, Derek Lowenstein. The Chairman is the designated Principal Investigator for the NASA Space Radiation Laboratory Facility.

#### **Responsibilities**

The Chairman for the Collider-Accelerator Department at BNL shall be administratively and fiscally responsible for the entire project. In particular he must do the following:

- Provides overall management oversight for all aspects of the project.
- Appoints the Contractor Project Manager.
- Approves key personnel appointments made by the Contractor Project Manager.
- Approves major subcontracts recommended by the Contractor Project Manager.
- Ensures that adequate staff and resources are available to complete EBIS in a timely and cost effective manner (within constraints of the budget provided by DOE).
- Ensures that EBIS has demonstrated that it meets the functional requirements.
- Provides documentation and access to information necessary for operation of EBIS at other sites.
- Ensures the work is performed safely and in compliance with the ISM rules.
- Reports to the Associate Laboratory Director for High Energy and Nuclear Physics regarding the operations of the Collider-Accelerator Department.
- Reports to Frank Sulzman, NASA, regarding NSRL operations.

### **5.2.4 Contractor Project Manager**

The Chairman for the Collider-Accelerator Department, Derek Lowenstein, has appointed James Alessi the EBIS Contractor Project Manager.

#### **Responsibilities**

The Contractor Project Manager shall report directly to the Chairman for the Collider Accelerator Department and will be in charge of the overall management of EBIS. The CPM shall appoint the key staff needed for the project with the approval of the Chairman for the Collider-Accelerator Department. The CPM also will have the following responsibilities:

- Responsible and accountable for the successful execution of contractor's project scope of EBIS.
- Supports FPD in implementing DOE project management process.
- Provides input on project documentation.

- Implements contractor performance measurement system.
- Delivers project deliverables as defined in this PEP.
- Identifies and ensures timely resolution of critical issues within contractor's control.
- Allocates the contingency funds according to the procedure defined in the Baseline Change Control (Section 7).
- Acts as the spokesperson for the project to the DOE and the scientific community.
- Collaborates with the Associate Lab Director for High Energy Nuclear Physics and the Chairman for the Collider-Accelerator Department to assemble the staff and resources needed to complete the project.
- Keeps the scientific community informed on the progress of the project.
- Appoints the Quality Assurance Manager (QAM).
- Provides monthly input to Federal Project Director to be used in report to DOE.
- Submits quarterly status reports to BHSO Federal Project Director.
- Ensures the work is performed safely and in compliance with the Integrated Safety Management (ISM) rules.
- Produces necessary Environment Safety and Health (ES&H) documentation (e.g., NEPA).
- Approves baseline changes up to Level 2.

### **5.2.5 Subsystem Managers**

The EBIS Project contains four major systems: the Source and Accelerator Structures, Electrical Systems, Facilities and Installation Support, and Mechanical Systems. The EBIS Contractor Project Manager has appointed managers to be responsible for the subsystems, which comprise the major systems. They are: Edward Beebe for Source & Accelerator Structures, Bob Lambiase for Power Supply Systems, Michelle Wilinski for Diagnostic Instrumentation, Donald Barton for Controls, Alexander Zaltsman for RF Systems, John Ritter for Magnet Systems, Mike Mapes for Vacuum Systems, Alexander Pendzick for Facility Modifications, Rosalbino (Russ) Grandinetti for Cooling Systems, and Louis Snydstrup for Installation. They will be responsible for the design, construction, installation, and testing of their subsystem, in accordance with the performance requirements, schedule, and budget.

### **Responsibilities**

- Collaborate with the CPM to assemble the staff and resources needed to complete the subsystem.
- Communicate the system design requirements to the staff.
- Ensure that subsystems meet the EBIS system design requirements, including interfaces.
- Responsible for carrying out the design, construction and assembly of the subsystem in accordance with the scope, schedule and budget, assuming funding and resources as described in the PEP.

- Provide regular reports on the status of the subsystem to the Contractor Project Manager.
- Ensure the work is performed safely and in compliance with the ISM rules.

### 5.2.6 Quality Assurance Manager

The CPM will assign the QAM.

### Responsibilities

- Collaborates with the CPM and Deputy Contractor Project Manager to ensure the quality of EBIS.
- Ensures that the quality system is established, implemented, and maintained in accordance with the EBIS Quality Assurance Plan.
- Provides oversight and support to the partner labs and institutions to ensure a consistent quality program.

## 5.3 INTEGRATED PROJECT TEAM

The composition of the EBIS Integrated Project Team (IPT) is given in Table 5-1. Its responsibilities are described in the DOE directive. The team will meet at least quarterly, or more frequently if necessary. The DOE Federal Project Director will chair the IPT.

Table 5-1. EBIS Integrated Project Team

DOE Federal Project Director (Chair)	Michael A. Butler
DOE Site Contracting Officer	Michael D. Holland
DOE Program Manager for EBIS	Jehanne Simon-Gillo
DOE Science Program Manager	Gulshan Rai
NASA Space Radiation Program Manager	Frank Sulzman
BNL Project Manager for EBIS	Jim Alessi
BNL Procurement Operations Manager	David E. Dale
BNL ESSH Lead	Ed Lessard
C-AD Assistant Chair for Administration	Stephanie LaMontagne

## 5.4 OPERATION PHASE

The EBIS will operate as the ion source and first stage injector to the RHIC facility. The ion source, RFQ and Linac form an injector chain for ion injection into the Booster synchrotron. This facility will be a permanent installation that is dedicated to providing ions to the Collider-Accelerator Department accelerator complex. RHIC will have first priority for these beams. In addition, when RHIC does not require its use, the EBIS injector chain can provide beams for the NASA NSRL)at the Booster or for beams to be

used at the AGS. The EBIS injector system operation will be totally integrated into the C-AD Pre-injector Group.

The cost of operations of the EBIS Pre-injector will be significantly lower than those of the Tandem. The Tandem facility requires a staff of approximately 12 FTE's to support maintenance and 24 hour shift rotation during operations. The EBIS pre-injector will require a staff of ~3 FTE's for operation and maintenance, since it should be able to run unattended at most times, and will be monitored by C-AD Main Control Room personnel. Operating cost savings are expected to be on the order of \$1.5-2 million per year.

## **5.5 LIFE CYCLE COSTS**

- Construction costs: described in this document
- Operation: it is expected that ~ 3 FTE's will be required to operate and maintain the EBIS pre-injector. Included is a core scientific, engineering, technical support from within the C-AD Preinjector Group, plus additional support at a smaller scale from other groups within C-AD (Controls, Diagnostics, Vacuum, Power Supply, Cooling Systems, RF, Drafting, etc.). Costs for electrical power and materials costs are expected to be lower than those required for Tandem operation.
- Decommissioning and decontamination: The EBIS pre-injector will be fully integrated with the rest of the C-AD complex, and has already been incorporated in the current Safety Assessment Document for the Department. Decommissioning and decontamination will be included as a part of the D&D of the RHIC facility. With the low final energy from the pre-injector for any ion species, there will be no activation of components, so D&D activities would involve either the disposal or reuse of standard scientific equipment.

## **6 SCHEDULE AND COST SCOPE**

EBIS has been organized into a Work Breakdown Structure (WBS) for purposes of planning, managing and reporting project activities. Work elements are defined to be consistent with discrete increments of project work. EBIS has thirteen major WBS Level 2 components: Structural Components, Controls Systems, Diagnostic/Instrumentation, Magnet Systems, Power Supply Systems, RF Systems, Vacuum Systems, Cooling Systems, Facility Modifications, Installation, Project Services, Commissioning and R&D.

### **6.1 PRELIMINARY SCHEDULE SCOPE**

Figure 6.1 shows a high level schedule of the key elements of the EBIS project. The WBS dictionary is available in Appendix A. The schedule is fully integrated to include both the DOE and NASA efforts.

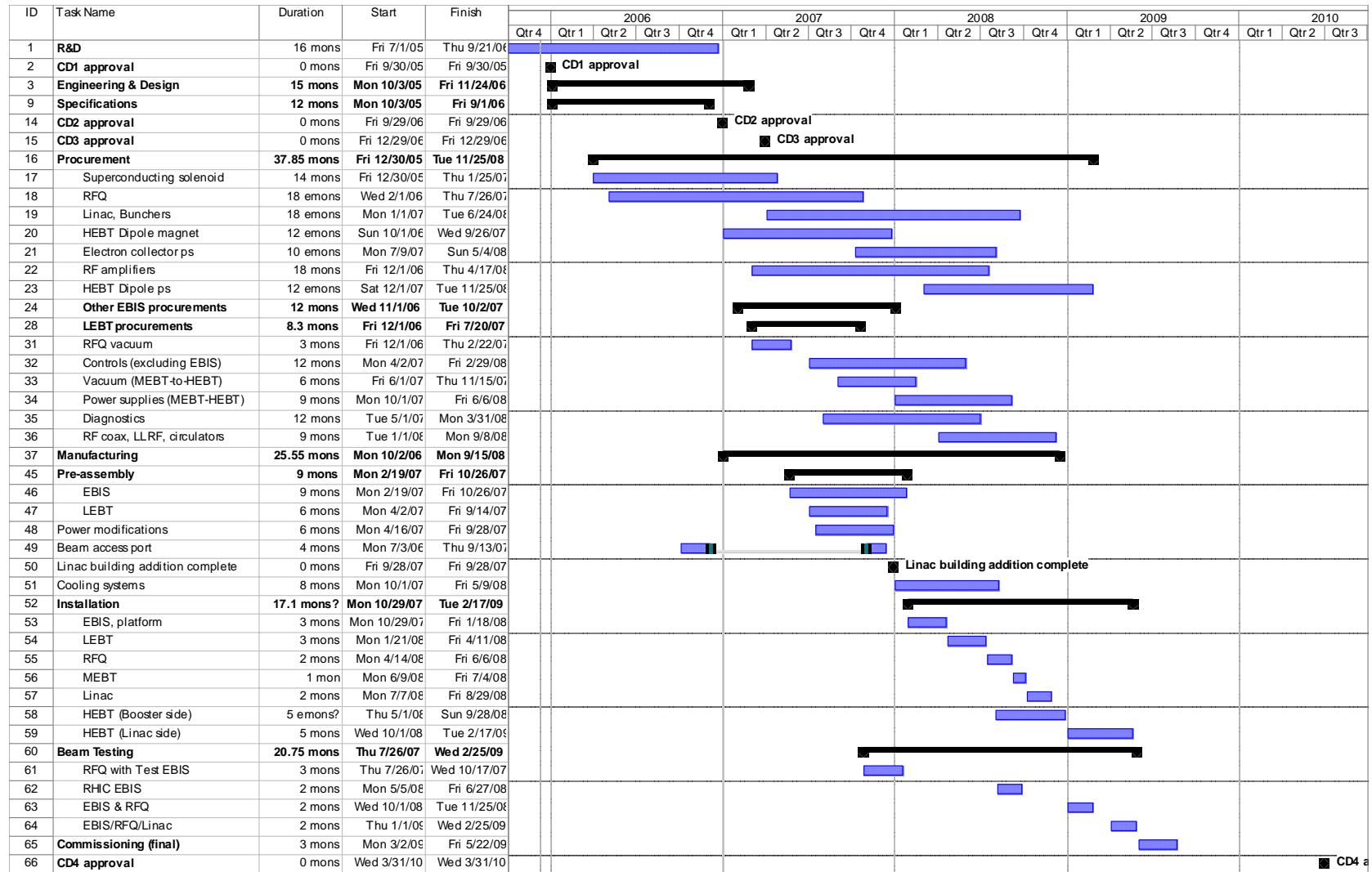


Figure 6.1 Preliminary high level schedule of the EBIS project

### 6.1.1 Milestones

Table 6-1 shows the preliminary milestones. Additional level 2 milestones will be established prior to CD-2.

Table 6-1 Preliminary EBIS Level 1 and Level 2 Milestones

Level	Major Milestones	Fiscal Years	Agency
1	CD-0 Approve Mission Need	Q4 2004 (A)	DOE
1	CD-1 Approve Preliminary Baseline Range	Q4 2005	DOE
1	CD-2 Approve Performance Baseline	Q4 2006	DOE
1	CD-3 Approve Start of Construction	Q1 2007	DOE
1	Beam accelerated to final energy	Q4 2009	DOE/NASA
1	CD-4 Approve Start of Operations	Q2 2010	DOE/NASA
2	Superconducting solenoid procurement placed	Q1, 2006	NASA
2	Electron collector procurement placed	Q1, 2006	DOE
2	RFQ procurement placed	Q2, 2006	NASA
2	R&D EBIS installed on high voltage platform	Q2, 2006	DOE
2	R&D high voltage beam tests begin	Q3, 2006	DOE
2	Electron collector ready for testing	Q3, 2006	DOE
2	EBIS PED complete	Q4, 2006	DOE
2	LEBT PED complete	Q4, 2006	DOE
2	Beam port installation initiated	Q4, 2006	NASA

## 6.2 PRELIMINARY COST SCOPE

Table 6-2 shows the estimated DOE TPC cost summary for the EBIS. Standard DOE escalation factors were assumed of 2.8% (2006) and 2.6% (2007-2009).

Table 6-2 Preliminary Cost Summary for EBS project.

WBS	Title	M\$
1.1	Structural components	1.8
1.2	Controls Systems	0.6
1.3	Diagnostics/instrumentation	0.7
1.4	Magnet Systems	0.3
1.5	Power Supply Systems	0.9
1.6	RF Systems	2.3
1.7	Vacuum systems	1.5
1.8	Cooling Systems	0.3
1.9	Facility Modifications	0.6
1.10	Installation	1.9
1.11	Project Services	0.6
1.12	Commissioning*	
1.13	R&D / CDR	0.7
subtotal		12.1
	Contingency	2.7
Total		14.8

\* Commissioning dollars are currently contained in the other WBS elements

### 6.2.1 Funding

The EBS project will be funded by DOE-NP and NASA. The DOE funding profiles at the CD-0 and CD-1 stages are shown in Table 6-3. (See Appendix B for NASA information.)

Table 6-3 Preliminary EBS Project Funding Profile

Fiscal Year	CD- 0 Budget Authority Profile (M\$)	CD- 1 Budget Authority Profile (M\$)
2005	1.6	0.7
2006	2.0	2.1
2007	2.0	7.5
2008	2.9	4.5
2009	2.0	0.0
2010	2.025	0.0
2011	6.3	0.0
2012	0.3	0.0
Totals	19.1	14.8

At CD-0, the DOE total project cost (TPC) range was set at \$16.0–\$19.5 million. Since that time, the project schedule has been accelerated in order to realize cost savings in RHIC operations sooner and to take advantage of NASA’s contributions to reduce the total cost of the project to DOE. With the NASA contribution and refinements during the project conceptual design, the preliminary estimate for the DOE TPC at CD-1 is now 14.8 M\$ and the estimated TPC range at CD-1 is \$12.1 - \$14.8 million. The DOE TPC is allocated as follows:

<b><u>Category</u></b>	<b><u>Cost (M\$)</u></b>
CDR	0.2
R&D	0.6
PED/EDIA	2.1
Construction	11.6
Pre-ops	0.3
<b>DOE TEC</b>	<b>13.7</b>
<b>DOE TPC</b>	<b>14.8</b>

### 6.2.2 Contingency

The FPD manages the contingency funds according to the DOE Order 413.3 procedure defined in the Baseline Change Control section and as specified in the Change Control table in Table 7-1. Table 6-4 shows the estimated average contingency rate by subsystem, utilized to develop the overall project contingency.

Table 6-4 Basis of Contingency Development

<b>WBS</b>	<b>Title</b>	<b>Average Contingency %</b>
<b>1.1</b>	<b>Structural components</b>	<b>20.8</b>
<b>1.2</b>	<b>Controls Systems</b>	<b>22.5</b>
<b>1.3</b>	<b>Diagnostics/instrumentation</b>	<b>20.0</b>
<b>1.4</b>	<b>Magnet Systems</b>	<b>25.0</b>
<b>1.5</b>	<b>Power Supply Systems</b>	<b>25.1</b>
<b>1.6</b>	<b>RF Systems</b>	<b>27.1</b>
<b>1.7</b>	<b>Vacuum systems</b>	<b>20.0</b>
<b>1.8</b>	<b>Cooling Systems</b>	<b>20.0</b>
<b>1.9</b>	<b>Facility Modifications</b>	<b>26.7</b>
<b>1.10</b>	<b>Installation</b>	<b>21.1</b>
<b>1.11</b>	<b>Project Services</b>	<b>20.0</b>
<b>1.12</b>	<b>Commissioning*</b>	
<b>1.13</b>	<b>R&amp;D / CDR</b>	<b>14.3</b>
	<b>Project Total</b>	<b>22.3</b>

\*Contingency for Commissioning is currently contained in above WBSs.

The contingency percentages were derived by estimating at the lowest level WBS/task item for cost, technical and schedule risks. The contingency rates are determined by considering the development status of the items, and the uncertainties plus risks in completing the construction and testing. Contingency percentage guidelines have been assigned to individual risk elements and vary from 10% to 40%. The guidelines used to establish the contingency percentages are listed Table 6-5. Averages are used when the risk levels in the technical and cost categories are different for a given item.

Table 6-5 Contingency Percentages

Technical Risk Description	Cost Risk Description	Schedule Risk Description	Contingency Rate
Direct copy of an existing, working design	Off the shelf hardware or purchased from a catalog	No schedule impact on any other WBS item	10%
Based on an existing design but requiring extensive modifications	Based on a vendor quote using limited conceptual design sketches	Delays completion of only its own non-critical path subsystem item	20%
New design different from established designs or existing technology	Estimate for item with little in-house experience	Delays completion of other non-critical path subsystem items	30%
New design requiring R&D to develop advanced state-of-the-art technology	Top down estimate derived from comparable previous programs	Directly delays completion of critical path subsystem item	40%

### 6.2.3 Research and Development (R&D)

The primary purpose of the R&D is to test the ion beam extraction, acceleration, and transport line focusing system presently being considered for matching the EBIS beam into the RFQ. R&D efforts will include the implementation of a test stand that will be used to test the RHIC EBIS electron collector design for thermal load handling. Finally, the test stand will be able to provide a beam at the required input energy for initial testing of the final RFQ at BNL prior to installation in the final location. These developments will serve to reduce technical and schedule risks on the project. The R&D includes the procurement of the full power electron collector, which will later be used on the RHIC EBIS. Procurement of a 100 kV isolation transformer, high voltage isolation, and some EBIS power supply modifications will allow the EBIS to be operated from a high voltage platform, producing beams at the final energy required for injection into the RFQ. Finally, a prototype of the final LEBT design will be built and tested. Completion of the R&D is scheduled for Q4 FY06.

## 7 CHANGE CONTROL

Changes to the technical, cost and schedule baselines will be controlled using the thresholds described in Table 7-1.

All changes that include or exceed Level 2 approval thresholds (as defined in Table 7-1) should first be submitted to the CPM using a Baseline Change Proposal (BCP). For changes exceeding Level 2, the CPM will endorse the request (i.e., recommend approval) to higher authority or reject the request. If endorsed, CPM will then transmit the BCP to the FPD with recommendations. If the request exceeds Level 1, the BHSO Baseline Change Control Board (BCCB) will submit the BCP to the FPD in DOE Headquarters for approval. All Level 1 BCPs will be reviewed and approved by the BHSO BCCB and all Level 2 BCPs will be reviewed and approved by the CPM.

The BHSO BCCB will consist of the EBIS FPD (chair), the BHSO Director, the Associate Director for HENP at BNL (or designee), the Chairman of the Collider-Accelerator Department, the CPM, and others as directed by the FPD. Technical advisors will be included as needed in the BHSO BCCB. The chair has the final responsibility to authorize or endorse the BCP. For Level 2 changes and requests for higher-level changes the CPM will consult with the Project Engineer.

If the change is approved, the copy of the approved BCP, together with any qualifications or further analysis or documentation generated in considering the request is returned to the requestor, and copies are sent to the official at the next higher control level and to EBIS for filing. If approval is denied, a copy of the BCP, together with the reasons for denial, is returned to the requestor, and a copy is filed. The official at the next higher control level may review the granted change to ensure proper application of the procedure and consistency of the change with the goals and boundary conditions of the project.

Table 7-1. Summary of Baseline Change Control Thresholds

<b>Level</b>	<b>Cost</b> (Table 6-2)	<b>Schedule</b> (Table 6-1)	<b>Technical Scope</b>
DOE-SAE (Deviation Threshold)	25% increase to TPC	6 or more months increase (cumulative) in a project level milestone date	Changes to scope that affect mission need requirement
DOE-SC-26 Program (Level 0)	Any increase in the TPC or cumulative allocation of more than \$500k contingency	3-month or more delay of a Level 1 milestone date	Change of any WBS element that could adversely affect performance specifications
DOE-BHSO Federal Project Director (Level 1)	A cumulative increase of more than \$250k in WBS Level 2 or cumulative allocation of more than \$250k contingency	> 1-month delay of a Level 1 milestone date or > 3-month delay of a Level 2 milestone date	Any deviation from technical deliverables that does not affect expected performance specifications
EBIS Contractor Project Manager (Level 2)	Any increase of >\$50k in the WBS Level 2	> 1-month delay of a Level 2 milestone date	Technical design changes that do not impact technical deliverables

## **8 ANALYSES, ASSESSMENTS AND PLANS**

### **8.1 ENVIRONMENT, SAFETY AND HEALTH**

#### **8.1.1 Purpose of the ESSH Chapter**

The purpose of this chapter is to briefly describe the rigorous environmental protection, safety, security, health and quality (ESSH) activities associated with the EBIS Project that will be completed prior to commencement of construction, commissioning and operations.

#### **8.1.2 Review of ESSH Issues Associated with the EBIS Design**

The shielding policy for this facility is the same as that for the rest of the Collider-Accelerator facilities since the new pre-injector and beam line are to be the responsibility of the Department. Specifically, the Collider-Accelerator Department's Radiation Safety Committee will review facility-shielding configurations to assure that the shielding has been designed to:

- Prevent contamination of the ground water.
- Limit annual site-boundary dose equivalent to less than 5 mrem.
- Limit annual on-site dose equivalent to inadvertently exposed people in non-Collider-Accelerator Department facilities to less than 25 mrem.
- Limit dose equivalent to any area where access is not controlled to less than 20 mrem during a fault event.
- Limit the dose equivalent rate to radiation-workers in continuously occupied locations to ALARA but in no case would it be greater than 0.5 mrem in one hour or 20 mrem in one week.
- Limit the annual dose equivalent to radiation workers where occupancy is not continuous to ALARA, but in no case would it exceed 1000 mrem.

In addition to review and approval by the Radiation Safety Committee, the Radiation Safety Committee Chair or the ESHQ Associate Chair must approve final shield drawings. Shield drawings are verified by comparing the drawing to the actual configuration. Radiation surveys and fault studies are conducted after the shield has been constructed in order to verify the adequacy of the shield configuration. The fault study methodology that is used to verify the adequacy of shielding is described and controlled by Collider-Accelerator Department procedures.

The DOE ESHQ requirements applicable to the new pre-injector are listed in Table 8-1. All hazards, including radiological hazards, associated with DOE accelerator facilities are addressed comprehensively in DOE Order 420.2A, Safety of Accelerator Facilities. Appropriate and adequate protection of workers, the public, and the environment from ionizing radiation is also covered under 10CFR1035, "Occupational Radiation Protection," which applies to all DOE facilities regardless of the source and type of ionizing radiation. The C-A Department implements the DOE requirements indicated in

Table 8-1 using procedures and training. At the BNL level, the Standards Based Management System (SBMS) is used to keep DOE requirements current and to flow requirements down to the Department level. At the C-A Department level, SBMS requirements are flowed down into routine operations procedures. All ESHQ requirements and hazard controls are documented in detail in the C-A Operational Procedures (OPM).

In order to meet the requirements in DOE Order 420.2A, Safety of Accelerator Facilities, C-AD has incorporated a description and safety assessment of the new pre-injector into the current [Safety Assessment Document for C-AD](#). At the appropriate time, the C-A Department will obtain an approved Accelerator Safety Envelope for the new pre-injector from DOE and perform an Accelerator Readiness Review in accord with Order 420.2A prior to commissioning and operations.

Table 8-1 Current DOE ESHQ Requirements for BNL Accelerators

Topic	DOE Requirements Document
Authorization Basis Documents	DOE O 420.2B, Safety of Accelerator Facilities DOE O 420.1A, Facility Safety (Natural Phenomenon and Fire Protection Sections)
Conduct of Operations	DOE O 54100.19 Chg 2, Conduct of Operations Requirements for DOE Facilities
Quality Assurance	DOE O 414.1B, Quality Assurance
Maintenance Management	DOE O 430.1B, Real Property Asset Management DOE O 430.2A, Departmental Energy And Utilities Management
Training and Qualification Programs	DOE O 54100.20A Chg 1, Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities
Radiation Protection	Title 10, Code of Federal Regulations, Part 1035, Occupational Radiation Protection
Transportation and Packaging	DOE O 460.2 Chg 1, Departmental Materials Transportation and Packaging Management DOE O 460.1B, Packaging and Transportation Safety
Worker Protection	DOE O 440.1A, Worker Protection Management for DOE Federal and Contractor Employees
Environmental Protection	DOE O 450.1, Environmental Protection Program DOE O 451.1B Chg 1, National Environmental Policy Act Compliance Program - Change 1
ESH Reporting	DOE O 231.1A, Environment, Safety, and Health Reporting
ESH Standards	DOE O 54100.4 Chg 4, Environmental Protection, Safety, and Health Protection Standards
Accident Investigation	DOE O 225.1A, Accident Investigations
Radioactive Waste Management	DOE O 435.1 Chg 1, Radioactive Waste Management

The C-A Department conforms to the requirements of ISO 14001, Environmental Management System, and OHSAS 18001, Occupational Safety and Health Management System, and achieves third-party registration for these internationally recognized management systems. Thus, in addition to DOE requirements, documentation of environmental protection and occupational safety and health programs for new pre-injector facilities will be prepared and audited by independent parties. This documentation will include:

- Environmental Process Evaluations for all processes with significant environmental aspects.
- Facility Risk Assessments for all facilities and areas.
- Job Risk Assessments for all jobs.

DOE O 420.1A, Facility Safety, has two sections that are applicable to accelerator facilities: Natural Phenomenon and Fire Protection Sections. DOE STD-1020-2002, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities, describes the Performance Criteria (PC) to be used for evaluating building design for earthquake, wind and flood phenomena. DOE-STD-1020-2002 employs the graded approach in assigning PC categories to DOE buildings. The graded approach enables cost-benefit studies to be used to address categorization. It is noted that the radioactivity entrained within the new pre-injector components would not have a significant off-site impact as a result of an earthquake, high winds or flood. Based on the small amounts of hazardous materials that will be present at the new pre-injector facilities, the PC1 category is applicable. That is, BNL will use model building codes for the new pre-injector facilities that include earthquake, wind, and flood considerations. BNL is currently using PC1 for all other C-AD facilities for life safety issues.

Significant environmental aspects of the new pre-injector project include:

- Excavation
- Chemical Storage/Use
- Liquid Effluent
- Hazardous Waste
- Radioactive Waste
- Radiation Exposures
- New or Modified Federal/State Permits

Based on the disposition of cooling tower discharge, the existing New York State Pollutant Discharge Elimination System (SPDES) permit would be revised as necessary. The cooling system would be a closed loop deionized water system using ion exchange beds that would be removed for regeneration or disposal by a contractor off site. In no case would the ion beam strike the water directly. At the proposed beam current and ion-beam energy, no induced activity would be expected. Discharge of contaminants to the ground or to the sanitary system would be neither planned nor expected from the cooling system. The closed loop cooling system would be connected to the cooling tower via a heat exchanger. Cooling-tower water would be treated either with ozone or with biocides and rust inhibitors, and would meet all SPDES effluent limits.

### **8.1.3 ESSH Plans for Construction**

All requests for goods or services will be processed through a formal and well-documented system of review to incorporate any special ESSH requirements of the contractor or vendor. BNL will review the proposed contract scope of work using [Work Planning and Control for Experiments and Operations](#) Subject Area. The building modification and utility drawings for the new pre-injector will be sent to the BNL's Safety and Health Services Division for review by the appropriate Environment, Safety and Health (ES&H) disciplines.

C-AD will define the scope of work with sufficient detail to provide reviewers and support personnel with a clear understanding of what is needed, expected, and required. This will include the type of work to be performed, location of work, defined contract limits, allowed access routes, and any sensitive or vulnerable laboratory operations or infrastructure that may be impacted by this work. The C-AD will ensure that facility hazards are characterized and inventoried specific to the expected construction location and activities.

The C-AD will ensure that minimum ESSH competency requirements for contractors are detailed and provided to the Procurement & Property Management Division (PPM). PPM will include those requirements in the bid and contract documents to qualify contractors for award. Competency requirements will be consistent with the project, facility and job to be performed.

#### **8.1.4 ESSH Plans for Commissioning, Operations and Decommissioning**

The Collider-Accelerator Department has already identified hazards and associated on-site and off-site impacts to the workers, the public and the environment from the C-AD accelerator facilities, including the new EBIS based pre-injector, for both normal operations and credible accidents. Sufficient detail was provided to DOE in the current [C-AD Safety Assessment Document](#) (SAD) to ensure that C-AD has performed a comprehensive hazard and risk analysis. The amount of descriptive material and analysis in the SAD related to both the complexity of the facility and the nature and magnitude of the hazards. In addition, the SAD provides an understanding of radiation risks to the workers, the public and the environment.

The risk analysis in the SAD addresses the hazards of the entire system of pre-injectors and accelerators. It also addresses hazards, controls and risks for all facilities such as pre-injectors, injectors, accelerators, experimental halls, experiments and their associated targets and detectors. The C-AD SAD follows the generally accepted principles identified in DOE Order 420.2B.

## **8.2 PROJECT QUALITY ASSURANCE PROGRAM**

### **8.2.1 Program**

The project, through the Collider-Accelerator (C-A) Department, shall adopt in its entirety the [BNL Quality Assurance \(QA\) Program](#). This QA Program describes how the various BNL management system processes and functions provide a management approach which conforms to the basic requirements defined in DOE Order 414.1B, Quality Assurance.

The quality program embodies the concept of the "graded approach;" i.e., the selection and application of appropriate technical and administrative controls to work activities, equipment and items commensurate with the associated environment, safety and health risks and programmatic impact. The graded approach does not allow internal or external

requirements to be ignored or waived, but does allow the degree of controls, verification, and documentation to be varied in meeting requirements based on environment, safety and health risks and programmatic issues.

The BNL QA Program shall be implemented within the Project using C-A QA implementing procedures. These procedures supplement the BNL Standards Based Management System (SBMS) documents for those QA processes that are unique to the C-A Department. C-A QA procedures are developed by C-A QA and maintained in the [C-A Operations Procedures Manual](#), Chapter 13.

The C-A QA philosophy of adopting the BNL Quality Program and developing departmental procedures for the implementation of quality processes within C-A ensures that complying with requirements will be an integral part of the design, procurement, fabrication, construction and operational phases of the Electron Beam Ion Source Project.

A Quality Representative has been assigned to serve as a focal point to assist C-A management in implementing QA program requirements. The Quality Representative has the authority, unlimited access, both organizational and facility, as personnel safety and training allows, and the organizational freedom to: assist line managers in identifying potential and actual problems that could degrade the quality of a process/item or work performance, recommend corrective actions, and verify implementation of approved solutions. All C-A personnel have access to the Quality Representative for consultation and guidance in matters related to quality.

### **8.2.2 Personnel Training And Qualifications**

The BNL [Training and Qualification Management System](#) within the Standards Based Management System (SBMS) supports C-A management's efforts to ensure that personnel working on EBIS are trained and qualified to carry out their assigned responsibilities. The BNL [Training and Qualification Management System](#) is implemented within the C-A Department with the [C-A Training and Qualification Plan of Agreement](#).<sup>1</sup>

### **8.2.3 Documents and Records**

The [BNL Records Management System](#) and controlled document Subject Areas within SBMS, supplemented by C-A procedures, provide the requirements and guidance for the development, review, approval, control and maintenance of documents and records.

C-A documents encompass technical information or instructions that address important work tasks, and describe complex or hazardous operations. They include plans, and procedures, instructions, drawings, specifications, standards and reports.

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<sup>1</sup> <http://www.agshome.bnl.gov/AGS/Accel/SND/Training/trainplan.pdf> C-A Department Training and Qualifications Plan

#### **8.2.4 Work Process**

Work is performed employing processes deployed through the BNL SBMS. SBMS Subject Areas are used to implement BNL-wide practices for work performed. Subject Areas are developed in a manner that provides sufficient operating instructions for most activities. However, C-A management has determined that it is appropriate to develop internal procedures to supplement the SBMS Subject Areas. These C-A procedures are bounded by the requirements established by the BNL Subject Areas.

Group leaders and technical supervisors are responsible for ensuring that employees under their supervision have appropriate job knowledge, skills, equipment and resources necessary to accomplish their tasks. Where applicable, contractors and vendors are held to the same practices.

#### **8.2.5 Design**

Design planning shall establish the milestones at which design criteria, standards, specifications, drawings and other design documents will be prepared, reviewed, approved and released. The design criteria shall define the performance objectives, operating conditions, and requirements for safety, reliability, maintainability and availability, as well as the requirements for materials, fabrication, construction, and testing. Appropriate codes, standards and practices for materials, fabrication, construction, testing, and processes shall be defined in the design documentation. Where feasible, nationally recognized codes, standards and practices shall be used. When those are either overly restrictive, or fall short of defining the requirements, they shall be modified, supplemented, or replaced by BNL specifications.

Specifications, drawings and other design documents present verifiable engineering delineations in pictorial and/or descriptive language representations of parts, components or assemblies for EBIS. These documents shall be prepared, reviewed, approved and released in accordance with C-A procedures. Changes to these documents shall be processed in accordance with the C-A configuration management program.

#### **8.2.6 Procurement**

Personnel responsible for the design or performance of items or services to be purchased shall ensure that the procurement requirements of the purchase request are clear and complete. Using the graded approach, potential suppliers of critical, complex, or costly items or services shall be evaluated in accordance with predetermined criteria to ascertain that they have the capability to provide items or services which conform with the technical and quality requirements of the procurement. The evaluation shall include a review of the supplier's history with BNL or other DOE facilities, or a pre-award survey of the supplier's facility. C-A personnel shall ensure that the goods or services provided by the suppliers are acceptable for intended use.

### **8.2.7 Inspection and Acceptance Testing**

The BNL Quality Management System within the SBMS, supplemented by C-A procedures, provides processes for the inspection and acceptance testing of an item, service or process against established criteria and provides a means of determining acceptability. Based on the graded approach, the need and/or degree of inspection and acceptance testing shall be determined during the activity/item design stage. Inspection/test planning has as an objective the prompt detection of nonconformances that could adversely affect performance, safety, reliability, schedule or cost.

## **8.3 RISK ASSESSMENT**

### Risk of not proceeding with the EBIS project:

If the new Linac-based pre-injector is not built, significant upgrades to the tandems will be required in order to ensure reliable long-term operation for RHIC. This has been discussed in Section 4.6.

### Technical, Cost and Schedule Risks:

The technical risks of the EBIS design are low. The successful EBIS ion source R&D program at BNL has greatly decreased any risk related to a source of this type reaching the planned performance requirements. A prototype EBIS has operated with the full required electron beam current of 10 A, which is a factor of 20 improvement over previous EBIS sources. Since EBIS scaling laws are very well understood, the scaling of the source output by a factor of 2 from the prototype is achieved by a straightforward doubling of the EBIS trap length, that is, by doubling the length of the superconducting solenoid. The development described in Section 6.2.3 helps minimize technical and schedule risk related to the LEBT design.

The RFQ and the Linac accelerators are both mature technologies, with very similar devices operating successfully at BNL as well as at other accelerator laboratories. The present plan is to procure these devices from laboratories where several similar units have been built previously.

Currency exchange risk – it is probable that the EBIS project will include foreign procurements. Due to the cost risk associated with an unfavorable dollar vs. Euro exchange rate change, an average contingency rate of 35% has been applied to several key items. In addition, risk will be reduced by placing early procurements of some of these key items.

Uncertainties in the Booster operation schedule (for RHIC or NSRL) may impact the EBIS project schedule. This risk will be minimized by careful management of the project, since the majority of work can proceed in parallel with Booster operations. The HEBT dipoles, which can only be installed during a Booster shutdown, will be procured early to allow large schedule float.

Delays in project funding due to a Congressional Continuing Resolution could delay the placement of several key long-lead procurements. This is perceived to be a high risk, so BNL will work closely with DOE and NASA to insure that adequate funds are available for key procurements, and there will be an attempt to avoid scheduling large procurements for the first quarter of a fiscal year.

## **9 PROJECT CONTROLS AND REPORTING SYSTEMS**

The EBIS project has been entered into the Project Assessment and Reporting System (PARS) and will be updated on a monthly basis by the FPD.

The CPM will lead monthly cost and schedule reviews and report the result to the FPD. In addition, he will lead quarterly overall cost, schedule and technical performance reviews and report the results to the BHSO-DOE office. The FPD will report progress to the DOE Program Manager on a quarterly basis. The FPD and CPM will participate in monthly teleconference calls with the DOE Office of Nuclear Physics. The Office of Nuclear Physics will conduct annual progress reviews with a panel of experts.

The standard BNL accounting system will be the basis for collecting cost data. A direct one-to-one relationship will be established between each WBS element of Level 2 or lower and a separate account code under the BNL accounting system.

Technical performance will be monitored throughout the project to insure conformance to approved functional requirements. Design reviews and performance testing of the completed systems will be used to ensure that the equipment meets the functional requirements.

## **APPENDIX A: WBS DICTIONARY**

This dictionary gives a succinct definition of some of the most important tasks included in the WBS and describes both DOE and NASA activities.

### **1.1 Structural Components**

#### **1.1.1 EBIS Hardware**

The mechanical components which comprise the EBIS source.

##### **1.1.1.1 SC Solenoid**

The superconducting solenoid is a major element of EBIS and its function is to focus the electron beam generated in the electron gun and maintain its diameter in a region of the ion trap. No shielding is planned for the solenoid in order to enable use of its magnet field “tails” for the electron beam transmission in areas where use of other coils is difficult. The required magnetic field in the center of solenoid is determined by the combination of parameters (cathode emission current density, ion confinement time, tolerated level of impurities, ability of the electron collector to dissipate certain power). The solenoid is located on the EBIS platform and should require minimum maintenance for refilling of cryogens. (A portion of this WBS is funded by NASA)

##### **1.1.1.2 Electron Gun**

The EBIS electron gun generates the electron beam used for the ionization and confinement of ions in a trap. Since the electron beam propagates through the areas with very low potentials and with different magnetic fields the requirements on the laminarity of the electron beam are high. For this reason the magnetic field on the cathode is high enough to determine formation of the electron beam in a cathode-anode gap. The cathode material (IrCe) provides high emission current density with a lifetime of several thousand hours. The electron gun chamber is separated from the rest of the EBIS by two gate valves, which in a case of gun failure allows replacement of whole gun unit by a new one without venting the gun chamber and venting only small buffer volume between gate valves.

##### **1.1.1.3 Drift Tube & Chamber Structures**

Drift tubes are installed along the EBIS axis to control ion trap operation and propagation of the electron beam. Drift tubes are electrically isolated from the ground and connected to the external power supplies via electrical feedthroughs in a vacuum jacket. Vacuum chambers form a vacuum envelope around the EBIS with the pressure of residual gas in the range of  $1 \times 10^{-10}$  Torr. Three gate valves separate different parts of the EBIS for the purpose of maintaining high vacuum in parts that are not vented during modification or repair.

##### **1.1.1.4 Stands, Platform Hardware**

This includes the mechanical support structures for the EBIS, the electron gun, the LEBT line, and the external ion sources. It also include the 100 kV insulating platform for the EBIS source and its associated power supplies, as well as the electrical system required to put a ramp on the EBIS trap electrodes for fast ion extraction.

#### 1.1.2 LEBT and External Ion Injection

The beamlines between the EBIS output and RFQ input.

##### 1.1.2.1 LEBT

The LEBT is a transitional portion of the pre-injector and is used for:

- transmission and forming for the injection into RFQ of the ion beam extracted from the EBIS,
- transmission of the ion beam from the external ion injector into the EBIS,
- diagnostic measurements of the ion beams (total ion current measurements, ion beam content measurements),
- vacuum pumping of the electron collector.

The LEBT consists of two vacuum chambers separated by a gate valve; it contains optical electrostatic elements (deflectors, lenses), magnetic lenses for focusing the ion beam into the RFQ and diagnostic elements.

##### 1.1.2.2 External Ion Injection

A set of two or more ion sources generating low charge state ions for injection into EBIS. This also includes ion optics, a switching station for electronically selecting the desired ion species for ion injection, ion current monitors, vacuum system and power supplies.

#### 1.1.3 RF Structures

Resonant cavities used to accelerate or decelerate (for bunching) the ion beam. When radiofrequency power is fed into these resonant cavities, the appropriate electric fields for acceleration or deceleration are produced.

##### 1.1.3.1 RFQ

The Radio Frequency Quadrupole (RFQ) is a resonant structure in which four long, continuous vanes or rods, machined with precise modulations and configured in a quadrupole geometry, provide bunching, focusing, and acceleration of the injected ion beam. This type of structure is able to provide efficient rf acceleration at the low energies ion beams have when initially extracted from an ion source. A 4-rod RFQ operating at 101.28 MHz is planned. (A portion of this WBS element is funded by NASA)

### 1.1.3.2 Linac

The Linac is a resonant structure, which generates time dependent axial electric fields to accelerate ions. When the rf field direction is reversed, the ion bunches are shielded from the decelerating fields by internal drift tubes. An “Interdigital-H” - type Linac operating at 101.28 MHz is planned. (A portion of this WBS element is funded by NASA)

### 1.1.3.3 Buncher Cavities

A resonant cavity in which the time dependent field in a gap is adjusted to decelerate the front of a beam bunch arriving at the gap, and accelerate the back of the bunch, so that all particles in the bunch arrive at a downstream point more closely spaced in time. By changing the phase of the cavity by 180 degrees relative to the bunch, it can be used to remove energy spread in the beam (“debuncher”) instead. (A portion of this WBS element is funded by NASA)

## 1.2 Controls

Networked, front-end interfaces will be connected via Ethernet to control console workstations and central C-AD servers. Full pulse-to-pulse modulation functionality will be provided. Custom application software will be provided as needed, but extensive re-use will be made of existing software designs with EBIS database additions.

### 1.2.1 Timing & Infrastructure

C-AD fiber optic infrastructure will be extended to the EBIS equipment area and a standard network switch and timing chassis will be provided. Workstations and monitor screens will be provided for console-level control access, along with supporting software and database configuration.

### 1.2.2 EBIS

Waveform generation and data acquisition for EBIS will be provided using the fiber-optically isolated PSI interface and VME function generator. The fiber link interface of these standard C-AD modules will be modified to operate at 50 to 100 kHz for this application. Additional fiber optic links will carry pulsed trigger signals to the high voltage platforms. Standard VME chassis will be provided. Minor modifications will be required to existing front-end software for the function generator. A custom console application program will be developed for power supply waveform control.

### 1.2.3 Accelerators & Beam Transport

Commercial and C-AD standard VME modules will be used to control magnet power supplies and beam-line instrumentation. Standard VME chassis assembly and timing modules will be provided for these systems and also for RF system interfaces. Front-end

software effort will be mainly configuration and database setup. Existing console programs for beam line diagnostics will be modified to include the EBIS transport lines.

### **1.3 Diagnostics/Instrumentation**

#### **1.3.1 Faraday Cup**

A fully destructive measurement is made when a detector head is plunged into the beam path to collect the entire ion beam. The captured charge is measured as a current in the processing electronics. Several types of detector heads can be employed depending on the characteristics of the desired measurement. Channeltrons or multichannel plates are used for fast high bandwidth response.

#### **1.3.2 Current Transformers**

A ferrite toroid wound with many turns of signal wire is positioned around a ceramic break in the beam transport, all enclosed in a protective shroud. This is used as a non-destructive technique to measure the ion beam current characteristics with respect to time. A separate set of wire turns on the toroid is used for injecting a calibration signal.

#### **1.3.3 Profile Monitors**

Transverse beam profiles are measured by plunging an array of thin wires into the beam path. Each of the wires collects the charge from the small portion of the ion beam it intercepts; this charge is detected as a current in the processing electronics.

### **1.4 Magnet Systems**

#### **1.4.1 EBIS Warm Solenoids**

The EBIS warm solenoids consist of three solenoid magnets. The electron gun solenoid is designed with water-cooled hollow conductors, pancake-style coils and no iron return. The electron gun coil provides the necessary field for proper electron beam launching and transport. The electron collector solenoid is similar in design to the electron gun solenoid. The electron collector solenoid focuses the beam to allow for proper electron collector operation. The remaining magnet, the LEBT solenoid, is a pulsed solenoid located directly in front of the RFQ. The LEBT solenoid focuses the EBIS beam into the RFQ. The design of the LEBT solenoid uses pancake coils with a laminated iron return similar in design to the BNL Optically Pumped Polarized Ion Source (OPPIS) LEBT solenoid.

#### **1.4.2 MEBT Quadrupoles**

The EBIS MEBT quadrupole magnets are used to provide the necessary focusing for beam transport between the RFQ output and the Linac input. The quadrupole magnets

have been sent to BNL from Los Alamos National Laboratory (LANL), where they were released from the LEDA project. These LANL quadrupole magnets have half the magnetic length needed for the EBIS MEBT. To produce the required magnetic length, two quadrupole magnets will be positioned closely together around each of the four original quadrupole magnet positions. The estimate includes the support system of magnets and necessary water manifolds.

#### 1.4.3 HEBT Dipoles

The HEBT dipoles are two similar  $73^\circ$  bending dipoles. The basic design of the dipoles is a C style with the open end facing the outer curve to allow the chamber to have a port for the Tandem-to-Booster (TTB) line into the Booster. The magnets will be constructed of laminations of different sizes which when assembled will produce the required bend shape. The magnet coils will be made of water-cooled hollow copper conductor. (A portion of this WBS element is funded by NASA)

#### 1.4.4 HEBT Quadrupole Magnets

The HEBT quadrupoles will be air-cooled Danfysik magnets. Originally used for other projects at BNL, these magnets are available for the EBIS beam line. These magnets will allow switching of values in  $\sim 1$  second for running of different magnetic rigidity beams.

### 1.5 Power Supply Systems

#### 1.5.1 EBIS

Power supplies to support EBIS itself:

- Solenoid, cathode, cathode heater, collector and grid supplies.
  - Platform bias supplies and the transformers to isolate them.
  - Drift tube supplies, Behlke switches, and transverse magnetic supplies.
- (A portion of this WBS element is funded by NASA)

#### 1.5.2 External Ion Injectors and LEBT

Power supplies to support two external ion sources, the transport from the ion sources to the LEBT, and the LEBT itself:

- Heater, arc pulser and extractor power grid supplies.
- Platform bias supplies and the transformers to isolate them.
- Supplies for electrostatic and electromagnetic steering elements and lenses.
- Mass analyzer and focusing solenoid power supplies.

#### 1.5.3 MEBT, IH LINAC, and HEBT

Power supplies for the MEBT, IH LINAC, and HEBT

- Pulsed quadrupole magnets and steering magnet power supplies.
- Linac drift tube quadrupole magnet power supplies.
- Pulsed bending magnet power supplies.

(A portion of this WBS element is funded by NASA)

## **1.6 RF Systems**

### **1.6.1 High Level RF**

The final rf amplifier stages powering the RFQ, Linac, and three bunchers. This also includes the coaxial transmission line connecting the amplifier outputs to the rf cavities.

### **1.6.2 Low Level RF**

The low power rf systems which provide the phase and amplitude controls for the high level rf systems, and frequency control for the resonant cavities.

## **1.7 Vacuum Systems**

### **1.7.1 Beampipes/Chambers**

Pipes or chambers that have vacuum pressure inside and provide a path for the ion to be transported, as well as provide a housing for special components inside the vacuum system.

### **1.7.2 Vacuum Instrumentation & Control**

A PLC-based control system used to monitor and control the vacuum system and components such as gauges, pumps and valves.

### **1.7.3 Vacuum Pumps**

Pumps used to evacuate or pump down a vacuum chamber from atmospheric pressure to the desired high vacuum or ultra-high vacuum range.

### **1.7.4 Vacuum Valves**

Manual or pneumatically operated valves used to isolate vacuum pumps and/or a section of the beam line from another section or vacuum chamber.

## **1.8 Cooling Systems**

The cooling system is comprised of three separate and independent closed loop systems that will run off the present Linac chilled water system and dissipate heat into the existing Linac cooling tower. Each system consists of individually skid-mounted components: a

pump/motor, filter, heat exchanger, expansion tank, temperature and pressure control valves, and water treatment as required. The active on-line deionized water controls on 2 of the systems maintain the required resistivity. The exception is for the rf structures, which will have a 4109 iron corrosion inhibitor control system.

A chilled water source is required to supply the necessary 70F temperature. The existing Linac chilled water system is the preferred choice.

## **1.9 Facility Modifications**

### **1.9.1 Beam Access Port**

A new access port for the EBIS beam line will be installed through the earth shielding from Linac to the Booster. (A portion of this WBS is funded by NASA)

### **1.9.2 Power modification**

Provides for the relocation of existing power & tray in the Linac area where the EBIS beam line will be installed.

## **1.10 Installation**

The major systems and components of the EBIS are installed at the facility site in building 930, including structural components, control systems, diagnostic and instrumentation systems, magnets, power supplies, RF systems, vacuum systems, and cooling systems. The installation effort also includes any minor additions or changes to the building and facility necessary to accommodate these systems and components.

### **1.10.1 Structural Components**

The major structural components installed in the facility include the Electron Beam Ion Source (EBIS), RFQ, and Linac. Other components will include smaller devices located in the LEBT, MEBT, and HEBT beam transport regions, such as auxiliary ion sources (LEBT), bunchers, electrostatic beam transport devices, and beam monitoring devices.

### **1.10.2 Controls**

Installation of controls for the entire project.

### **1.10.3 Diagnostics/Instrumentation**

Installation and checkout of all diagnostics in the beamlines.

### **1.10.4 Magnet Systems**

The magnet systems installed in the beam transport line include dipole, quadrupole, and solenoidal magnets, and steerers. Also includes survey of elements.

#### 1.10.5 Power supply Systems

Installation of all power supplies in their final locations, the connection of power from breaker boxes to the supplies, and the connections from the power supplies to the elements.

#### 1.10.6 RF Systems

Installation of the rf power supplies, as well as the connection of the coaxial transmission line between the rf amplifiers and the rf cavities.

#### 1.10.7 Vacuum Systems

Installation of beampipes, chambers, pumps, and valves. Also includes the leak checking and bakeout of systems.

#### 1.10.8 Cooling Systems

Installation of all cooling systems.

### **1.11 Project Services**

Level of effort tasks associated with the daily management, oversight, and assessment of the project.

#### 1.11.1 Project Management & Support

This WBS contains the effort associated with the Project Office at BNL for the EBIS. The effort includes: the CPM, Project Controls, installation and conventional facilities coordination, financial oversight, documentation and reporting, and the Project Office secretary.

## APPENDIX B: NASA ITEMS

Since CD-0 approval, a Statement of Work between BNL and NASA has been signed, in which NASA will contribute \$4.5M (AY \$) to the project costs. These funds allow the schedule to be accelerated to approximately four years. Within the overall EBIS project, items have been identified for acquisition with these funds. The NASA scope includes the Radio Frequency Quadrupole, the Linac and bunchers, the EBIS superconducting solenoid, the HEBT dipole magnets, a beam access port, and various power supplies. A detailed list follows the funding tables.

NASA Funding: the planned levels of funding per fiscal year are as follows:

Fiscal Year	Funding profile (M\$)
2005	0.5
2006	1.5
2007	1.5
2008	1.0
Totals	4.5

Application of NASA funds:

WBS	Title	M\$
1.1	Structural components	1.5
1.2	Controls Systems	0.0
1.3	Diagnostics/instrumentation	0.0
1.4	Magnet Systems	0.3
1.5	Power Supply Systems	1.1
1.6	RF Systems	0.0
1.7	Vacuum systems	0.0
1.8	Cooling Systems	0.0
1.9	Facility Modifications	0.1
1.10	Installation	0.0
1.11	Project Services	0.0
1.12	Commissioning*	
1.13	R&D / CDR	0.5
subtotal		3.5
	Contingency	1.0
Total		4.5

\* Commissioning dollars are currently contained in the other WBS elements

Planned use of NASA funds by current task identifier		
<b>1.1</b>	<b>Structural Components</b>	
	1.1.1.1	SC Solenoid
	1.1.1.1.6	Procure solenoid & ps
	1.1.1.1.7	Procurement and Vendor interface and inspection
	1.1.1.1.8	Vendor site inspection (2)
	1.1.1.1.11	Incoming inspection
	1.1.1.1.13	Onsite installation service
	1.1.3.1	RFQ
	1.1.3.1.4	Procurement
	1.1.3.1.5	Travel to vendor
	1.1.3.1.6	Shipping
	1.1.3.1.7	Incoming inspection
	1.1.3.2	Linac
	1.1.3.2.4	Procurement
	1.1.3.2.5	Travel to vendor
	1.1.3.2.6	Shipping
	1.1.3.2.7	Incoming inspection
	1.1.3.3	Bunchers
	1.1.3.3.4	Procurement
	1.1.3.3.5	Shipping
	1.1.3.3.6	Incoming inspection
<b>1.4</b>	<b>Magnet Systems</b>	
	1.4.3	HEBT dipoles
	1.4.3.7	Procurements
	1.4.3.7.1	Laminations
	1.4.3.7.2	Coils
	1.4.3.7.3	Magnet stands
	1.4.3.7.4	Jacks
	1.4.3.7.5	Bus terminations
	1.4.3.7.6	Water manifolds
	1.4.3.8	Vendor visits (2)
	1.4.3.14	Procurement/Vendor interface and inspection
	1.4.3.15	Incoming inspection
<b>1.5</b>	<b>Power Supplies</b>	
	1.5.1.2.3	Alternate anode PS
	1.5.1.2.6	Electron Collector PS
	1.5.1.2.7	Ion extractor PS
	1.5.1.2.8	Suppressor PS
	1.5.1.3.1	Drift tube PS
	1.5.2.1.3	Platform bias PS
	1.5.2.1.5	Lens PS
	1.5.3.1	MEBT Materials
	1.5.3.1.1	Quad PS
	1.5.3.1.2	Steerer PS
	1.5.3.1.3	Racks
	1.5.3.2	IH LINAC Materials
	1.5.3.2.1	Quad PS
	1.5.3.3	HEBT Materials
	1.5.3.3.2	Big bend dipole PS
	1.5.3.3.3	Quad PS
	1.5.3.3.4	Steerer PS
	1.5.3.3.5	Racks
	1.5.3.4.3	Travel
<b>1.9</b>	<b>Facility Modifications</b>	
	1.9.1	Beam Access Port
	1.9.1.6	Disc/reconnect LTB equipment
	1.9.1.7	Remove/install equipment
	1.9.1.8	contract supervision
	1.9.1.9	port installation contract
	1.9.1.10	as-builts & design changes

## GLOSSARY

AGS	Alternating Gradient Synchrotron
ALARA	As Low As Reasonably Achievable
BCCB	Baseline Change Control Board
BCP	Baseline Change Proposal
BHSO	Brookhaven Site Office
BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates
CAA	Clean Air Act
C-A	Collider-Accelerator
C-AD	Collider-Accelerator Department
CD-0	Critical Decision - 0
CD-1	Critical Decision – 1
CD-2	Critical Decision - 2
CD-3	Critical Decision – 3
CD-4	Critical Decision - 4
CDR	Conceptual Design Report
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERN	Conseil Européen pour la Recherche Nucléaire (European Laboratory for Particle Physics)
CFR	Code of Federal Regulations
CGC	Color Glass Condensate
CPM	Contractor Project Manager
DART	Days Away or Restricted Time
DOE-HQ	U.S. Department of Energy – Headquarters
EBIS	Electron Beam Ion Source
ECR	Electron Cyclotron Resonance
EMR	Experience Modification Rates
EMS	Environmental Management System
EPA	Environmental Protection Agency
ES&H	Environment, Safety and Health
ESHQ	Environment, Safety, Health and Quality Assurance
ESSH	Environmental Protection, Safety, Security, Health and Quality
FPD	Federal Project Director
FTE	Full Time equivalent
FY	Fiscal Year
HEBT	High Energy Beam Transport
HEDP	High Energy Density Physics
HENP	High Energy & Nuclear Physics
IH	Inter-Digital H Structure
IPT	Integrated Project Team
ISM	Integrated Safety Management
ISO	International Organization for Standardization

LEBT	Low Energy Beam Transport
LINAC	Linear Accelerator
LIS	Laser Ion Source
LOTO	Lock-Out/Tag-Out
LTB	Linac to Booster
MEBT	Medium Energy Beam Transport
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NP	Nuclear Physics
NSRL	NASA Space Radiation Laboratory
NYSDEC	New York State Department of Environmental Conservation
OBS	Organization Breakdown Structure
OPM	Operational Procedures Manual
OPPIS	Optically Pumped Polarized Ion Source
OSHA	Occupational Safety and Health Act
PARS	Project Assessment and Reporting System
PC	Performance Criteria
PED	Project Engineering and Design
PEP	Project Execution Plan
PLC	Programmable Logic Controller
PPM	Procurement & Property Management Division
QA	Quality Assurance
QAM	Quality Assurance Manager
R&D	Research & Development
RCRA	Resource Conservation Recovery Act
RFQ	Radio Frequency Quadrupole
RHIC	Relativistic Heavy Ion Collider
SA	Self-Assessment Program
SAD	Safety-Assessment Document
SBMS	Standards Based Management System
SC	Office of Science
SDWA	Safe Drinking Water Act
SPDES	State Pollutant Discharge Elimination System
STD	Standard
TEC	Total Estimated Cost
TPC	Total Project Cost
QAP	Quality Assurance Program
WBS	Work Breakdown Structure